CLAIMS

I/We claim:

[c1] 1. A method in a computer system for locating a heart sound, the method comprising:

providing sound data and ECG data corresponding to a beat of a heart;

identifying an ECG measurement based on the ECG data; and

identifying the location of a heart sound within the beat based on analysis of the sound data and the ECG measurement.

[c2] 2. The method of claim 1 wherein the heart sound is anyone of an S1, S2, S3, or S4.

[c3] 3. The method of claim 1 wherein the sound data and ECG data correspond to the same beat of the heart.

[c4] 4. The method of claim 1 including:

defining a window in which the heart sound is expected to occur within the beat; and

identifying the location of the heart sound as a location within the sound window based on a measured sound amplitude.

[c5] 5. The method of claim 4 wherein the heart sound is S1 and the window is defined starting approximately at Q-onset.

[c6] 6. The method of claim 5 wherein the window extends for approximately 150 milliseconds.

[c7] 7. The method of claim 4 wherein the identified location of the heart sound within each of a plurality of beats is a fixed interval from the R peak of the beat, the fixed interval being derived from an average location of the maximum amplitude within the window.

[c8] 8. The method of claim 4 wherein the heart sound is S2 and the window is defined as starting approximately at the Q-onset plus 12.5% of the R-R interval plus 200 milliseconds.

[c9] 9. The method of claim 8 wherein the window extends for approximately 180 milliseconds.

[c10] 10. The method of claim 4 wherein the heart sound is S3 and the window is defined starting at an offset from S2, the offset corresponding the first positive peak in the second difference of the sound data after S2.

[c11] 11. The method of claim 10 wherein the window extends for approximately 130 milliseconds.

[c12] 12. The method of claim 4 wherein the heart sound is S4 and the window is defined starting approximately at Q-onset minus 2/3 of the P-R interval.

[c13] 13. The method of claim 12 wherein the window extends for approximately Q-onset minus a time interval based on a filter transient response time.

[c14] 14. The method of claim 4 wherein the location of a heart sound is the average of the locations within the beats of the centroids of the sound signal within the window.

[c15] 15. A method in a computer system for indicating the presence of a heart sound, the method comprising:

providing sound data corresponding to a beat of a heart;

analyzing the sound data to identify the location of a heart sound; and

outputting an indication of the identified location of the heart sound within a beat.

[c16] 16. The method of claim 15 including providing ECG data corresponding to the beat of the heart and wherein the analyzing uses the ECG to identify the location of a heart sound.

[c17] 17. The method of claim 15 wherein the outputting includes displaying a graphic representation of a sound signal of the beat and wherein the indication identifies the location within the displayed graphic representation.

[c18] 18. The method of claim 15 wherein the heart sound is S3.

[c19] 19. The method of claim 15 wherein the heart sound is S4.

[c20] 20. The method of claim 15 wherein the analyzing includes locating the geometric centroid of the sound signal of the heart sound.

[c21] 21. The method of claim 15 wherein the analyzing includes determining which beats have the heart sound and using those beats to identify the location of the heart sound.

[c22] 22. A method in a computer system for detecting a heart sound, the method comprising:

providing sound data and ECG data corresponding to a beat of a heart of a patient;

identifying an ECG measurement based on the ECG data; and

detecting the presence of a heart sound within the beat based on analysis of the sound data and the ECG measurement.

[c23] 23. The method of claim 22 wherein the heart sound is S3.

[c24] 24. The method of claim 22 wherein the heart sound is S4.

[c25] 25. The method of claim 22 wherein the sound data and ECG data correspond to the same beat of the heart.

[c26] 26. The method of claim 22 including:

defining a window within each beat in which the heart sound is expected to be located; and

identifying the presence of the heart sound based on the amplitude within the window.

[c27] 27. The method of claim 22 wherein the heart sound is detected based on comparison of the amplitude within a window in which the heart sound is expected to be located to the amplitude within a window in which another heart sound is expected to be located.

[c28] 28. The method of claim 27 wherein the other heart sound is S1.

[c29] 29. The method of claim 27 wherein the other heart sound is S2.

[c30] 30. The method of claim 27 wherein the comparison includes calculating a ratio of the amplitudes.

[c31] 31. The method of claim 30 wherein a heart sound is detected within a beat when the calculated ratio satisfies a threshold ratio.

[c32] 32. The method of claim 31 wherein the threshold ratio varies based on beat-to-beat correlation information.

[c33] 33. The method of claim 31 wherein the threshold ratio varies based on signal-to-noise information.

[c34] 34. The method of claim 22 wherein the beat is categorized as not, possibly, or probably having the heart sound.

[c35] 35. The method of claim 22 including indicating that the heart sound is detected in the patient based on the number of beats in which the heart sound is detected.

[c36] 36. The method of claim 35 wherein the heart sound is detected in the patient when the number of beats is a certain percentage of the total number of beats.

[c37] 37. The method of claim 36 wherein the total number of beats excludes invalid beats.

[c38] 38. The method of claim 22 wherein the heart sound is detected in the patient based on the number of beats categorized as possibly having the heart sound and the number of beats categorized as probably having the heart sound.

[c39] 39. The method of claim 22 wherein the ECG measurement is Q-onset.

[c40] 40 The method of claim 22 wherein the ECG measurement is the PR interval.

[c41] 41. The method of claim 22 wherein the ECG measurement is the R peak.

[c42] 42. The method of claim 22 wherein the detecting includes filtering the sound data into frequency bands and analyzing the sound data in each frequency band.

[c43] 43. The method of claim 22 wherein sound data represents an average beat.

[c44] 44. A system for detecting a heart sound, comprising:

a component that filters sound data into frequency bands;

a component that identifies a frequency band for detection of the heart sound;

a component that defines a window within each beat of the sound data where the heart sound is expected to be located;

a component that classifies each beat based on characteristics of the filtered sound data within the defined window of the identified frequency band; and

a component that indicates the presence of the heart sound based on the classification of the beats.

[c45] 45. The system of claim 44 wherein the heart sound is an abnormal heart sound and the classification of each beat is based on a reference amplitude derived from a normal sound of the sound data.

[c46] 46. The system of claim 44 wherein each beat is classified as invalid, not having the heart sound, possibly having the heart sound, or probably having the heart sound.

[c47] 47. The system of claim 46 wherein the presence of the heart sound is indicated based on number of beats classified as possibly or probably having the heart sound relative to the number of beats not having a heart sound.

[c48] 48. The system of claim 47 wherein the heart sound is S3.

[c49] 49. The system of claim 47 wherein the heart sound is S4.

[c50] 50. The system of claim 44 wherein the identification of the frequency band is based on analysis of signal-to-noise floor ratio of the filtered sound data.

[c51] 51. A computer-readable medium containing instructions for controlling a computer system to detect an abnormal heart sound by a method comprising:

filtering sound data into frequency bands;

identifying a frequency band for detection of the heart sound;

defining a window within each beat of the sound data where the heart sound is expected to be located;

classifying each beat based on characteristics of the filtered sound data within the defined window of the identified frequency band; and

indicating the presence of the heart sound based on the classification of the beats.

[c52] 52. The computer-readable medium of claim 51 including determining the location of the heart sound within a beat.

[c53] 53. The computer-readable medium of claim 52 including displaying an indication of the location of the heart sound relative to a beat.

[c54] 54. The computer-readable medium of claim 51 wherein the defining of the window uses ECG data.